MOISTURE PROTECTION FOR TIMBER MEMBERS

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SUMMARY

This research evaluated sealers and coating systems for protecting softwood and hardwood bridge timbers treated with creosote and CCA preservative systems. Fractional moisture contents after 47 days of moisture adsorption for CCA treated southern pine end grain specimens was lowest for two coats of epoxy compared to the controls and the unfinished CCA treated control. All of the other finishes provided less moisture retardation. Similar results were obtained for the transverse grain CCA treated southern pine specimens. After 47 days of testing the CCA treated red maple results were somewhat different than the southern pine results. Two coats of epoxy provided the best protection from moisture gain through the end grain of CCA treated red maple followed by two coats of roof cement. Two coats of other finishes had higher moisture gain and similar retardation to each other. The best finish for transverse grain CCA treated red maple was two coats of epoxy. All other finishes had comparable 47-day factional moisture contents to the controls (untreated and unfinished). In general, the finishes provided some retdation in the moisture gain in the creosote treated specimens during the first one or two days of testing for both species and grain directions. After the first two or three days, the moisture gain was not retarded. Epoxy was the only notable exception to the moisture gain retardation of the finishes on creosote treated wood. One coat of epoxy on creosote treated southern pine and red maple end grain and transverse grain specimens produced substantial reductions in the rate of moisture gain and fractional moisture content values. Two coats of epoxy more than doubled the one coat reduction in the 47-day fractional moisture content for southern pine and red maple end grain and transverse grain speciments.

INTRODUCTION

Wood preservatives are used to prevent biological deterioration of wood especially for wood exposed to the exterior enviroment. Solid sawn and glued-laminated timber bridge members in the United States are treated in accordance with the American Wood-Preservers' Association Standards (1994). Preservative treating cycles are designed to penetrate the wood members creating an envelope of preservative around the outside of the bridge timber. The retention in this penetrated area is quite high and is designed to provide adequate protection from biological deterioration (AWPA, 1994).

If the protective preservative treatment envelope is broken the untreated wood in the interior of the wood bridge members may be exposed to biological attack The preservative protective barrier that has been penetrated by drilling or cutting during construction may be restored using field treatments at the construction site. Moisture induced checking or splitting through the protective barrier during service may be corrected by field treatments provided the surfaces are accessible. Checking and splitting in joints and connections may not be repaired easily in the field.

In order to minimize moisture induced damage to the protective envelope in preservative treated timber bridge members and to provide maximum service-life for wood bridges, it would be prudent to develop a data base for coatings and sealers that will retard moisture movement into the treated wood and effectively protect the wood.

Moisture movement in preservative-treated wood has been reported by Hornicsar, Blankenhorn and Webb (1987). The vapocup method was used in this study to determine rates of moisture movement in the transverse direction and to calculate water-vapor permeability values for CCA- and creosote-treated red oak and southern pine. In most instances, the rates of moisture movement were greater for southern pine than for red oak under the same conditions. CCA treated specimens had the highest water-vapor permeability values while creosote treated specimens had the lowest for each species.

Feist and Ross (1995) reported on the durability properties of 15 different commercial finishes that were used on untreated and CCA treated southern pine and hem-fir boards. This study did not measure rate of moisture movement through the finish into the wood and concentrated on finish durability. In another study, Feist Little, and Wennesheimer (1985) reported on the moisture excluding effectiveness (MEE) of 91 finishes on wood. This study did not report moisture excluding effectiveness of finishes on preservative treated wood.

Oil borne, waterborne, and organic solvent preservative systems require different types of sealers and coatings and selected bridge components require a specialized sealer or coating. Bridge rails, railposts, and curbs are highly visible bridge components compared to deck panels, end walls, diaphragms or beams. Highly visible bridge components require sealers or coatings that maintain aesthetics. Less visible bridge components have less emphasis on aesthetics.

Oil Borne, waterborne and organic solvent-based preservatives are used to treat wood. Creosote and pentachlorophenol in heavy oil are similar preservative systems relative to their moisture excluding effectiveness with creosote being a more widely used preservative. The most widely used waterborne preservative system is CCA.

There are many sealer and coating systems that may be investigated. Organic-based sealers and coatings are susceptible to ultraviolet degradation and will need maintenance. Inorganic-based coatings and sealers are not susceptible to ultraviolet degradation but must be compatible with wood.

Water repellents (WR) and water-repellent preservative (WRP) finishes are typically water, oil or solvent based. Typical formulations for WR and WRP are given in Feist and Mraz (1978). Oil-based WR and WRP are typically formulated with linseed oil or tung oil. Solvent-based systems may use mineral spirits, turpentine, paint thinner or another volatile solvent. The water “proof’ or water “repelling” part of the mixture is the oil, wax, alkyl resins, acrylic latex or silicon.

Inorganic systems are usually not considered as a sealer or coating for wood structures but are currently used as moisture barriers and sealers on concrete. These systems are not affected by ultraviolet radiation, and arc oil-based (organic) or water-based (inorganic). The oil systems are usually based on linseed oil and we quite similar to the oil-based systems used as finishes for wood. The water-based inorganic systems are either silanes or silicates.

Water-based systems are latex systems, which are usually film forming and opaque. Bituminous coatings (roof cement) and impregnated felts or similar membrane systems are currently used on timber bridges. These systems are completely opaque and are not compatible with the aesthetics of wood structures. Thermosetting systems are usually expensive but have excellent moisture excluding properties. Thermosetting systems may be semi-transparent like epoxy *or* opaque like resorcinol formaldehyde and silicon rubber.

A recent development by Hickson Corp. and Koppers Industries, Inc. is an oil or wax system for use in treating and sealing the surface of CCA impregnated wood for exterior service. This system holds considerable promise for both waterborne and oil borne preservative treated wood. It also has the advantage of being transparent and as such will be compatible with the aesthetics of wood structures.

The objective of this research is to evaluate existing and potential sealers and coating systems for protecting softwood and hardwood bridge timbers treated with oil borne and waterborne preservative systems.

EXPERIMENTAL

Moisture protection for wood bridge components will need to consider the following: wood species; type of preservative; and sealers and coatings.

The softwood species group and hardwood species used in this study were southern pine and red maple. The two preservative systems used in the research were creosote and CCA. The number of finishes, descriptions given in Table 1, tested in this project included the water repellent/water proof sealers commercially available (one system each from Thompson’s, Severe Weather, Wolman, Valspar, and

Olympic), oil/wax emulsion (Hickson Corp. and Kopper's Industries, Inc.), epoxy resin, bituminous coating (roofing cement), and a water soluble silicate solution.

This project was designed to obtain empirical data on the moisture movement through finishes applied to preservative treated wood. Moisture movement through the transverse direction (end groin of the wood sealed) and the end grain (transverse direction of the wood sealed) was obtained for finished and unfinished preservative treated wood. The end grain or transverse direction of the wood was sealed with a polyester fiberglass resin to significantly retard moisture movement in the sealed direction. The transverse direction specimens, with the end grain sealed were 0.5 inches square in cross section by 5 inches long. End grain moisture absorption specimens, with the transverse direction sealed, were 3.5 inches wide by 1.5 inches thick by 0.5 inches long. All specimens were ovendried after being cut to size and stamped with a reference number. Moisture adsorption data were analyzed on a per ovendry gram of wood basis. After the ovendry weight was obtained, all specimens were conditioned to 12% equilibrium moisture content (EMC) and the appropriate surface sealed. The specimens were again weighed and divided into three groups 1) control (untreated and unfinished); 2) preservative treated (unfinished); and 3) finished/preservative treated. Each group of specimens for each wood species contained six replications for both end and transverse grain moisture adsorption.

The preservative treated specimens were sent to Koppers Industries, Inc for treatment with creosote and Hickson, Corporation for CCA treatment. Upon return, the CCA treated specimens were weighed and conditioned in a 12% EMC room. The creosote treated specimens received a low-temperature surface steam cleaning after which they were weighed and conditioned at 12% EMC. The specimens after conditioning had the appropriate surface coated with selected finishes.

The moisture adsorption specimens were submerged in liquid water. Water uptake was obtained at 24-hour intervals for five days then each week until equilibrium was reached.

The moisture content were calculated based on moisture adsorbed and ovendry weight. The fictional moisture content values were normalized to the fractional moisture content value determined for a time frame that was very close to equilibrium or steady state adsorption.

All data were analyzed using analysis of variance procedures to determine significant differences. The level of significance for all tests was 0.05. Comparisons were made among finishes on a preservative treatment and between a finish on different preservative treatments.

RESULTS AND DISCUSSION

The fractional moisture contents were normalized to the fractional moisture content value obtained after 47 days of moisture adsorption in liquid water. Examination of the moisture adsorption data inidcated that at 47 days the rate of moisture adsorption was at or very close to steady state. The normalization allowed the comparison among treatment groups of the initial moisture adsorption rates.

Normalized fractional moisture content values for the end grain and transverse grain southern pine and red maple controls (untreated and unfinished) and the CCA, CCA/oil, CCA/wax, and creosote treated specimens are listed in Table 2. The initial (less than 2 days of moisture adsorption) normalized fractional moisture content values for the controls were very similar to the CCA, CCA/oil, and CCA/wax treated *southern* pine specimens for both groin directions.. Red maple control specimens had similar normalized factional moisture content values, for the first two days of moisture adsorption, as the CCA treated specimens for the end grain and transverse groin directions. However, the CCA/oil and CCA/wax treatments influenced the normalized fractional moisture content values for the initial two days of moisture adsorption. The red maple CCA/oil treated specimens had higher values while the red maple CCA/wax had lower values than the red maple control specimens. The CCA/wax treatment retarded the initial moisture adsorption in the red maple specimens.

All of the CCA treated southern pine end grain specimens (Table 3) finished with one coat of the selected finishes retarded moisture adsorption for the first five days compared to the controls except those specimens finished with Val-Oil, Thompson's, and "N" Silicate. The Val-Oil Finish did impart some retardation of the moisture movement during the first day of testing. Two coats of each finish produced similar results as one coat during the first five days of the test.

Similar results were obtained for the transverse grain CCA treated southern pine specimens (Table 3). All of the specimens with one coat of finish slowed moisture adsorption during the first five days compared to the control specimens except those specimens finished with Val-Oil, Olympic, Thompson's, and "N" Silicate. The Val-Oil and the "N" Silicate did provide some retardation for the first day of the test. A second coat of each finish produced exactly the same result as the specimens finished with one coat except that the Val-Oil retarded moisture adsorption for the first two days of testing.

End grain red maple specimens treated with CCA and finished with one coat of the selected finishes (Table 3) had retarded moisture adsorption for the first five days compared to the control specimens except for the Thompson's finished specimens. Two coats of each finish produced exactly the same results as the specimens finished with one coat of the selected finishes.

Transverse grain CCA treated red maple specimens (Table 3) had somewhat different results. The moisture adsorption for the first five days was retarded compared to the controls by one coating of each selected finish except for the Val-Oil, Olympic, Thompson's and "N" Silicate finished specimens. Two coatings produced similar results to the single coated specimens. The exception to this statement is Val-Oil. Two coats of Val-Oil retarded moisture adsorption compared to one coating indicating an improvement in the performance of the finish.

Comparison of the time required for the controls and the CCA, CCA/oil, and CCA/wax specimens to adsorb 50% of the moisture adsorbed after 47 days of soaking in liquid water (Table 4) provided additional information on the retardation of moisture adsorption. The time required for the southern pine and red maple controls (untreated and unfinished) to reach 50% of the 47-day uptake was very comparable to the CCA, CCA/oil, and CCA/wax treated specimens for both grain directions. This indicated a minimum retardation to the rate of moisture adsorption.

The finished end grain CCA treated southern pine specimens (Table 4) had numerous finishes that retarded the time for 50% of the 47-day moisture adsorption. Only Thompson's and "N" Silicate, one and two coars, did not retard the time to reach 50% moisture adsorption compared to the controls. All other finishes retarded the time required reach 50% of 47-day moisture adsorption value. In fact, Severe Weather, Enterprise, Wolman, roof cement, and epoxy were four times longer for one coat than the 3 days for the controls and 2 to 3 times better than the CCA treated (unfinished) specimens. Two coats improved the moisture adsorption retardation by six times.

The transverse grain moisture gain retardation for the finished CCA treated southern pine specimens (Table 4) was not as spectacular as the end grain results. However, all one coat finishes were equal to or slightly better than the control (untreated and unfinished) and CCA treated (unfinished) time to reach 50% of the 47 day moisture uptake. One-day additional increase was observed for two coats of Val-Oil, Enterprise, and Wolman finishes. Two coats of epoxy retarded the moisture gain by 4 times compared to the control and CCA treated specimens.

Somewhat similar results were observed for the red maple specimens (Table 4). For one coat of finish on the end grain specimens, Thompson's equaled the time for 50% moisture gain at 47 days for the controls and the CCA treated specimens. All other one coat finishes improved the time to 50% moisture gain with roof cement, epoxy, Severe Weather, Enterprise, and Wolman being 4-5 times better than the controls and the CCA treated specimens with two coats of finish. Enterprise and epoxy were 12 and 19 times, respectively, better than the controls and the CCA treated specimens.

Transverse groin CCA treated red maple specimens 50% moisture gain times (Table 4) indicated that all finishes were equal to or better than the controls (untreated and unfinished) and CCA treated (unfinished specimens. Two coats of finish improved the retardation of the time to 50% of the 47-day moisture gain for Val-Oil, Enterprise and epoxy finishes. Two coats of epoxy finish provided over six times the moisture gain retardation compared to the red maple controls and CCA treated specimens.

Statistical analyses of one coat versus two coats for each finish after one day moisture gain provided insight into the initial moisture gain retardation. Analysis for the one coat CCA treated southern pine end grain specimens versus two coats indicated that

Severe Weather, Val-Oil, Enterprise, Olympic, roof cement, and epoxy were significantly different For the transverse grain specimens, Enterprise, Val-Oil, Olympic, and epoxy finishes were significantly different. One coat of Thompson's, Val-Oil, Wolman, and epoxy was significantly different than two coats for the end grain red maple specimens. Two coats of Severe Weather, Val-Oil, Enterprise, Olympic, roof cement, "N" Silicate and epoxy finishes were significantly different from one coat for the transverse grain red maple specimens.

The moisture gain performance of the test specimens varied by species, direction, and finish. The only initial retardation in moisture gain for the CCA, CCA/Oil, and CCA/Wax specimens was for the CCA/Wax transverse grain red maple compared to the controls (untreated and unfinished) and the CCA controls (unfinished). The initial retardation in moisture gain carried through to the 47-day fractional moisture content values.

Fractional moisture contents after 47 days for CCA treated southern pine end grain specimens was lowest for two coats of epoxy compared to the controls and the unfinished CCA treated control. All of the other finishes provided some moisture retardation with "N" Silicate providing the minimal retardation in moisture gain. Similar results were obtained for the transverse grain CCA treated southern pine specimens.

In contrast to the southern pine fractional moisture content results, after 47 days of testing CCA treated red maple results were more restrictive. Two coats of epoxy provided the best protection from moisture gain through the end grain of CCA treated red maple followed by two coats of roof cement. Two coats of the other finishes provided similar moisture gain retardation to each other. The best finish for transverse grain CCA treated red maple was two coats of epoxy followed by two coats of Val-Oil. All other finishes had comparable 47-day fractional moisture contents to the controls (untreated and unfinished).

Two coats of epoxy on end and transverse grain CCA treated southern pine and red maple specimens had the lowest fictional moisture content values compared to the controls and all other treaments. The 47-day fractional moisture content values after two coats of epoxy were 80% lower for end grain CCA treated southern pine, 68% lower for transverse grain southern pine, 73% lower for end grain red maple, and 72% lower for transverse grain red maple compared to their respective controls.

The oil-based creosote treated specimens (Table 2) produced somewhat contrasting results compared to the water borne CCA treated specimens. Some of the finish formulations contained compounds that were solvents for the creosote solutions. In some instances, creosote may have inhibited the setting of the finish.

The creosote (Table 2) itself in the creosote treated southern pine and red maple end grain and transverse grain specimens retarded moisture gain as a function of time compared to the controls (untreated and unfinished). This retardation was attributed to the oil in the creosote.

In general, the finishes provided some retardation in the moisture gain in the creosote treated specimens (Table 5) during the first one or two days of testing for both species and gain directions. After the first two or three days, the moisture gain was not retarded and the normalized factional moisture contents were comparable to the values for the corresponding unfinished creosote treated specimens. Examination of the fractional moisture content values after 47 days of testing indicated that the fractional moisture contents for the creosote treated specimen were very similar to the one and two coat finished specimens. Severe Weather, Val-Oil, Enterprise, Olympic, Wolman, and Thompson's were fomulated for exterior use on CCA treated material. Water soluble "N" Silicate was not compatible with the oil based creosote. The roof cement was asphalt based and certain fractions of the creosote were solvents for the cement. This contributed to the relatively poor performance of the roof cement with the creosote treated southern pine and red maple specimens.

Epoxy (Table 5) was the notable exception to the moisture gain retardation of the finishes on creosote treated wood. One coat of epoxy on the southern pine and red maple end grain specimens retarded moisture gain better than one or two coats of all the other finishes, It resulted in a 47-day fractional moisture content reduction from the creosote control value of 13% for southern pine and 17% for red maple. The transverse grain specimens had better results. One coat of epoxy results in a 47-day transverse grain tractional moisture content reduction from the creosote control value of 23% for southern pine and 28% for red maple.

Two coats of epoxy (Table 5) produced striking results. For the end grain specimens, the 47-day fractional moisture content reduction from the creosote control value was 62% for southern pine and 51% for red maple. Transverse grain, 47-day fractional moisture content reduction from the creosote control value was 62% for southern pine and 63% for red maple.

One coat of epoxy on creosote treated southern pine and red maple end grain and transverse grain specimens produced substantial reductions in the rate of moisture grain and fractional moisture content values. It is clear that the two coats of epoxy more than doubled the one coat reduction in the 47-day fractional moisture content for southern pine and red maple end groin and transverse grain specimens.

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Finish Code	Finish Trade Name	Finish Composition
A	Severe Weather	Mineral Spirits; Aromatic naphtha; light modified resin; aliphatic petroleum distillates; aliphatic hydrocarbon resin; 1, 2, 4-trimethylbenzene
B	Val-Oil	Mineral Spirits; modified alkyd resin; zirconium octoate; methyl ethyl; ketoxime; cobalt soap
C	Enterprise	Mineral Spirits; aromatic naphtha; aliphatic petroleum distillates; modified resin; petroleum; hydrocarbon resin cyclopenta; 1, 2, 4-trimethylbenzene; xylene; ethylbenzene
D	Olympic	Naphtha (8042-41-3); paraffin waxes; hydrocarbon waxes; linseed oil; modified dicyclopentadiene; naphtha (64742-95-6); 1, 2, 4-trimethylbenzene
E	Wolman	600 g/liter max VOC
F	Thompson's Ultra	400 g/liter VOC; less than 10% Petroleum distillates;
G	Plastic Roof Cement	Asphalt; petroleum distillate; encapsulated asbestos; limestone
H	Epoxy	Epoxy Resin, Amine Hardener
I	"N" Silicate	Silicic Acid; Sodium Salt; Water

Table 1. Composition of Selected Finishes Used to Seal CCA and Creosote Treated Southern Pine and Red Maple.

Specimen Group[1]	------ Day ------- 1	3	5	12	FM[3] Day 47
Southern Pine End Grain					
Controls	.43	.53	.60	.71	1.13
CCA Controls	.41	.47	.50	.62	1.25
CCA/Oil	.47	.56	.62	.72	1.20
CCA/Wax	.42	.51	.54	.63	.99
Creosote	.31	.56	.67	.90	.37
Southern Pine Transverse Grain					
Controls	.41	.50	.60	.71	.79
CCA Controls	.46	.51	.54	.70	.77
CCA/Oil	.45	.54	.57	.66	.90
CCA/Wax	.44	.54	.56	.62	.69
Creosote	.29	.46	.62	.83	.34
Red Maple End Grain					
Controls	.59	.77	.81	.88	.99
CCA Controls	.52	.69	.75	.88	1.16
CCA/Oil	.73	.85	.88	.91	1.02
CCA/Wax	.44	.60	.68	.78	1.05
Creosote	.42	.61	.73	.95	.41
Red Maple Transverse Grain					
Controls	.32	.55	.66	.79	.87
CCA Controls	.40	.56	.64	.79	.92
CCA/Oil	.43	.60	.68	.82	.84
CCA/Wax	.33	.49	.58	.72	.77
Creosote	.23	.40	.51	.69	.38

Table 2. Moisture Content Gain During Water Soak of Unfinished Controls and CCA, CCA/Oil, CCA/Wax, and Creosote Treated Southern Pine and Red Maple Specimens.

Specimen Group	Coats	Approximate Days to 50% of the Total 47-Day Moisture Gain: End Grain So. Pine	End Grain Red Maple	Transverse Grain So. Pine	Transverse Grain Red Maple
Unfinished					
Controls		3	1	3	3
CCA		5	1	3	2
CCA/Oil		2	1	2	2
CCA/Wax		3	2	2	3
Finished					
Severe	1	12	5	5	5
	2	12	5	5	3
Val-Oil	1	2	3	2	2
	2	3	4	4	5
Enterprise	1	12	5	4	3
	2	19	12	5	5
Olympic	1	5	3	2	3
	2	5	3	2	3
Wolman	1	12	4	3	5
	2	12	5	4	5
Thompson's	1	1	1	1	2
	2	1	1	1	2
Roof Cement	1	12	12	5	12
	2	12	12	5	12
Epoxy	1	12	5	5	12
	2	12	19	12	19
"N" Silicate	1	1	2	4	3
	2	1	2	3	3

Table 4. Approximate Times to 50% of the Total Moisture Gain at 47 Days for Southern Pine and Red Maple Specimens.

Specimen Group[1]	NFMC[4] (One Coat)				FMC[3]	NFMC[4] (Two Coats)				FMC[3]
	-------- Day -------				Day	-------- Day -------				Day
	1	3	5	12	47	1	3	5	12	47
Southern Pine End Grain										
Severe Weather	.28	.33	.39	.56	.70	.28	.33	.39	.56	.84
Val-Oil	.43	.57	.62	.72	.88	.34	.51	.57	.69	.84
Enterprise	.23	.37	.42	.55	.73	.20	.29	.32	.44	.80
Olympic	.38	.47	.51	.62	1.03	.33	.42	.48	.60	1.01
Wolman	.27	.37	.43	.56	.95	.26	.35	.41	.54	.96
Thompson's	.55	.58	.61	.68	1.04	.57	.60	.62	.68	.90
Roof Cement	.30	.38	.44	.52	1.14	.20	.30	.42	.51	1.01
Epoxy	.40	.45	.48	.64	.81	.19	.31	.40	.57	.23
"N" Silicate	.58	.59	.62	.67	1.09	.51	.56	.60	.66	1.24
Southern Pine Transverse Grain										
Severe Weather	.33	.43	.50	.67	.53	.33	.43	.52	.69	.57
Val-Oil	.31	.58	.64	.74	.50	.19	.45	.54	.69	.45
Enterprise	.24	.47	.55	.64	.59	.17	.40	.49	.62	.61
Olympic	.49	.61	.65	.73	.70	.43	.59	.65	.73	.62
Wolman	.36	.50	.57	.68	.62	.34	.46	.53	.66	.55
Thompson's	.59	.63	.66	.72	.61	.55	.60	.63	.70	.60
Roof Cement	.27	.42	.51	.62	.79	.24	.37	.49	.66	.63
Epoxy	.24	.41	.51	.65	.37	.07	.23	.34	.51	.25
"N" Silicate	.38	.48	.53	.57	.91	.39	.50	.55	.59	.75
Red Maple End Grain										
Severe Weather	.30	.41	.52	.76	.97	.27	.36	.45	.69	.98
Val-Oil	.27	.59	.73	.88	.98	.23	.43	.56	.78	1.12
Enterprise	.18	.39	.52	.75	1.04	.17	.32	.41	.59	1.09
Olympic	.33	.55	.69	.81	1.20	.33	.56	.70	.82	1.13
Wolman	.28	.47	.59	.79	1.07	.24	.40	.52	.74	1.07
Thompson's	.65	.75	.79	.86	1.12	.56	.71	.77	.84	1.19
Roof Cement	.11	.21	NA[5]	.56	1.00	.11	.20	.29	.50	.76
Epoxy	.30	.41	.49	.65	.92	.07	.14	.22	.39	.27
"N" Silicate	.46	.61	.70	.84	1.14	.47	.62	.72	.84	1.12
Red Maple Transverse Grain										
Severe Weather	.28	.40	.51	.73	.86	.40	.53	.63	.82	.83
Val-Oil	.37	.58	.65	.79	.82	.21	.43	.52	.68	.68
Enterprise	.24	.53	.63	.78	.87	.22	.44	.52	.69	.80
Olympic	.35	.54	.64	.80	.84	.32	.52	.65	.82	.86
Wolman	.26	.44	.53	.70	.88	.25	.47	.48	.63	.82
Thompson's	.45	.60	.71	.83	.85	.42	.57	.66	.79	.84
Roof Cement	.15	.34	.44	.61	.76	.13	.24	.34	.50	.82
Epoxy	.24	.36	.45	.61	.47	.06	.14	.23	.42	.24
"N" Silicate	.37	.53	.63	.76	.88	.34	.52	.61	.74	.83

Table 3. Normalized Fractional Moisture Content Gain During Water Soak of Finished CCA Treated Southern Pine and Red Maple End Grain and Transverse Grain Specimens

[1] Each specimen group contains six specimens.

[2] Fractional moisture content normalized to measurement Day 47.

[3] Average fractional moisture content on Day 47.

[4] Normalized Fractional Moisture Content.

[5] NA means data not available.

Specimen Group[1]	NFMC[4] (One Coat)				FMC[3] Day 47	NFMC[4] (Two Coats)				FMC[3] Day 47
	-------- Day -------					-------- Day --------				
	1	3	5	12		1	3	5	12	
Southern Pine End Grain										
Severe Weather	.32	.49	.63	.85	.36	.34	.50	.63	.84	.38
Val-Oil	.27	.54	.66	.88	.38	.26	.54	.66	.89	.38
Enterprise	.25	.53	.68	.94	.33	.26	.55	.68	.94	.39
Olympic	.28	.53	.69	.95	.37	.28	.52	.68	.92	.40
Wolman	.34	.55	.71	.96	.33	.34	.54	.70	.93	.34
Thompson's	.31	.55	.77	.99	.35	.33	.56	.78	1.00	.36
Roof Cement	.29	.53	.72	1.00	.33	.24	.44	.60	.90	.40
Epoxy	.23	.33	.44	.68	.32	.08	.12	.18	.38	.14
"N" Silicate	.41	.72	.88	1.00	.35	.34	.67	.82	.97	.34
Southern Pine Transverse Grain										
Severe Weather	.26	.38	.48	.71	.36	.26	.37	.48	.73	.33
Val-Oil	.26	.46	.57	.80	.36	.20	.37	.47	.72	.34
Enterprise	.26	.47	.58	.86	.34	.21	.38	.48	.74	.35
Olympic	.29	.46	.60	.83	.33	.29	.47	.60	.83	.37
Wolman	.32	.48	.59	.80	.32	.27	.40	.51	.76	.33
Thompson's	.32	.49	.63	.85	.35	.34	.49	.64	.87	.32
Roof Cement	.15	.31	.44	.75	.34	.05	.15	.24	.51	.37
Epoxy	.07	.12	.18	.38	.26	.06	.10	.15	.34	.13
"N" Silicate	.33	.52	.62	.81	.35	.22	.45	.57	.79	.28
Red Maple End Grain										
Severe Weather	.28	.43	.54	.69	.39	.27	.40	.51	.69	.37
Val-Oil	.22	.43	.53	.75	.37	.24	.45	.54	.71	.41
Enterprise	.22	.38	.47	.69	.39	.21	.39	.48	.71	.41
Olympic	.28	.42	.52	.72	.43	.26	.42	.53	.74	.41
Wolman	.24	.38	.49	.69	.36	.27	.39	.49	.70	.39
Thompson's	.29	.43	.55	.75	.40	.30	.41	.52	.74	.42
Roof Cement	.17	.35	.46	.75	.37	.29	.46	.55	.76	.39
Epoxy	.17	.26	.35	.56	.34	.06	.10	.15	.36	.20
"N" Silicate	.40	.68	.75	.93	.38	.42	.65	.74	.95	.37
Red Maple Transverse Grain										
Severe Weather	.21	.35	.47	.68	.34	.20	.32	.42	.62	.54
Val-Oil	.15	.33	.42	.64	.42	.12	.31	.39	.60	.33
Enterprise	.14	.29	.37	.84	.62	.24	.48	.62	.34	.30
Olympic	.21	.37	.50	.74	.38	.20	.35	.49	.74	.39
Wolman	.23	.37	.48	.68	.39	.21	.34	.49	.71	.36
Thompson's	.22	.36	.50	.72	.41	.23	.36	.50	.73	.36
Roof Cement	.11	.30	.42	.66	.44	.13	.32	.46	.74	.34
Epoxy	.05	.09	.16	.43	.27	.04	.07	.11	.31	.14
"N" Silicate	.28	.51	.61	.77	.46	.17	.41	.54	.71	.32

Table 5. Normalized Fractional Moisture Content Gain During Water Soak of Creosote Treated Southern Pine and Red Maple End Grain and Transverse Grain Specimens

[1] Each specimen group contains six specimens.

[2] Fractional moisture content normalized to measurement Day 47.

[3] Average fractional moisture content on Day 47.

[4] Normalized Fractional Moisture Content.

PTEC '99

PACIFIC TIMBER ENGINEERING CONFERENCE

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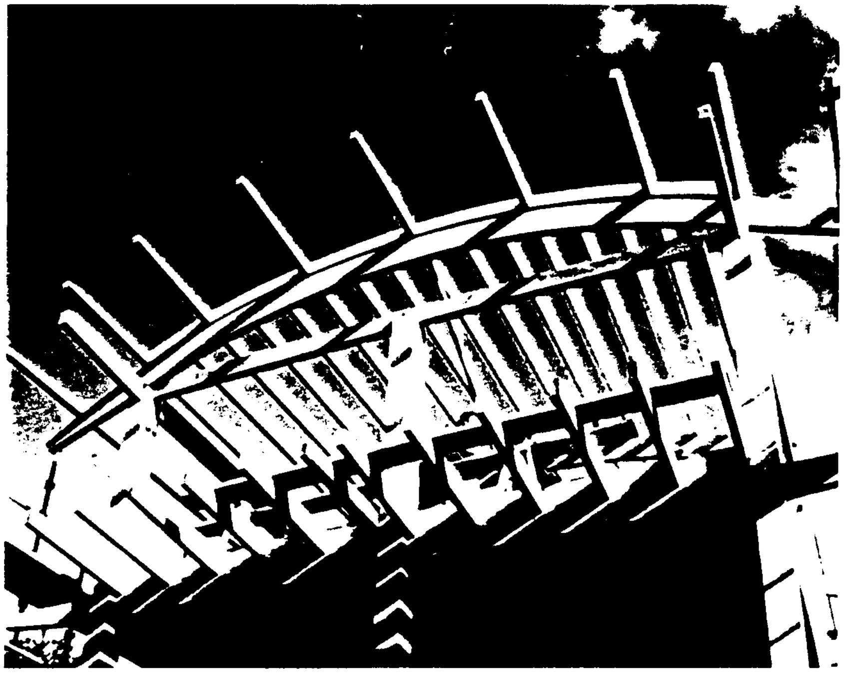

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